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Genetic and Phenotypic (Co)Variances for Production Traits of Intact Male Populations of Purebred and Composite Beef Cattle[1,2]

K. E. Gregory[3], L. V. Cundiff, and R. M. Koch[4]

Roman L. Hruska U.S. Meat Animal Research Center, ARS, USDA, Clay Center, NE 68933

ABSTRACT: Least squares means, genetic (σ_g) and phenotypic (σ_p) standard deviations, and phenotypic coefficients of variation (CV) were estimated for growth traits of intact males from 12 breed groups combined, for nine purebreds combined, and for the F_1, F_2, F_3, and F_4 generations of three composite populations to which the nine purebreds contributed. Heritabilities (h^2) and genetic (r_g) and phenotypic (r_p) correlations were estimated for growth traits, calving difficulty of calves with dams of different ages, and gestation length. Coefficients of variation and σ_g generally were similar for composites and contributing purebreds. Generally, estimates of h^2 were similar for all breed groups combined, contributing purebreds combined, and composites combined. Estimates of h^2 for calving difficulty were higher for calves with 2-yr-old dams than for calves with dams ≥ 3 yr old and were sufficiently high (.27 and .31) to be a useful selection criterion for reducing calving difficulty. Mean h^2 pooled within all breed groups ranged from .35 for 200-d weight and 368-d weight to .48 for 368-d height. Estimates of h^2 for subjective scores of anatomical traits were only slightly lower than those for growth and size traits. The h^2 of scrotal circumference (.43) was similar to those for growth and size traits. Genetic correlations between birth weight and calving difficulty were similar for 1) calves with dams of all ages, 2) calves with 2-yr-old dams, and 3) calves with dams ≥ 3 yr old. The r_g of gestation length with birth weight was low (.21) and was .57 and .54, respectively, with calving difficulty score and with percentage calving difficulty for calves with dams ≥ 3 yr old. Phenotypic correlations were relatively high among growth and size traits and were intermediate between birth weight and both expressions of calving difficulty in calves with 2-yr-old dams (.53 and .42) but were lower for calves with dams in other age classes.

Key Words: Cattle, Growth, Calving Difficulty, Heritabilities, Genetic Correlations, Phenotypic Correlations

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Introduction

Heritability estimates and genetic and phenotypic correlations for growth traits and between growth traits and calving difficulty have been reported (Mohiuddin, 1993; Koots et al., 1994a,b). Comparison of composite populations and their contributing purebreds for genetic and phenotypic variation has not been reported. Gregory et al. (1994a,b) suggested composite breeds as an effective procedure to use heterosis and breed differences to achieve and maintain optimum additive genetic composition for specified production and marketing situations. Gregory et al. (1991a,b,c,d; 1992a,b,c) reported results showing that retention of heterosis in composite populations is generally proportional to retention of heterozygosity and that composites offer a simpler procedure than continuous crossbreeding for using heterosis and a more effective procedure for using breed differences to optimize additive genetic composition for specified production and marketing situations. The objective of this study was 1) to estimate genetic and phenotypic variances and heritabilities of, and genetic and phenotypic correlations among, growth traits, calving difficulty, and gestation length of composite and contributing purebred populations of cattle.

Materials and Methods

Experimental Animals. There were 7,536 intact males by 713 sires included in this study (Table 1). Composite MARC I was 1/4 Braunvieh, 1/4 Limousin,

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[3]To whom correspondence should be addressed.

[4]Anim. Sci. Dept., Univ. of Nebraska, Lincoln 68583-0908.

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Table 1. Number of sires and individuals by breed group – intact males

Breed group	No. of sires	No. of individuals
Red Poll	40	425
Hereford	50	492
Angus	71	755
Limousin	48	482
Braunvieh	49	461
Pinzgauer	27	228
Gelbvieh	41	383
Simmental	58	459
Charolais	45	430
MARC I - F_1, F_2, F_3, F_4	105	1,081
MARC II - F_1, F_2, F_3, F_4	101	1,454
MARC III – F_1, F_2, F_3, F_4	78	886
Total	713	7,536

1/4 Charolais, 1/8 Hereford, 1/8 Angus; Composite MARC II was 1/4 Gelbvieh, 1/4 Simmental, 1/4 Hereford, 1/4 Angus; and Composite MARC III was 1/4 Red Poll, 1/4 Pinzgauer, 1/4 Hereford, 1/4 Angus. Composite populations included the F_1, F_2, F_3, and F_4 generations. Experimental animals were born from 1978 to 1991. Composite populations were formed from the same genetic base that was represented in the nine contributing parental breeds. Contributing purebred contemporaries to composites were maintained for Pinzgauer since 1982 and for all other breeds since 1978. The first 3/4 Pinzgauer were produced in 1980, 7/8 Pinzgauer (purebred in females) were produced in 1982, and 15/16 Pinzgauer (purebred in males) were produced since 1984.

The Braunvieh population averaged between 3/4 and 7/8 Braunvieh and was established by using semen from nine Braunvieh sires originating in Switzerland and the Federal Republic of Germany (Bavaria) on a foundation of purebred (registered and unregistered) Brown Swiss females obtained from dairy herds in Wisconsin and Minnesota as calves in 1967 and 1968. The grading from Brown Swiss to Braunvieh started in 1969. The Simmental, Limousin, Gelbvieh, and Pinzgauer populations were established by using 20 or more sires of each breed grading from purebred females from the same Hereford and Angus populations used in the experiment (except as noted). Grade-up programs to these breeds started at the U.S. Meat Animal Research Center in 1969 for Simmental, in 1970 for Limousin, in 1975 for Gelbvieh, and in 1977 for Pinzgauer. A sample of 3/4 Gelbvieh females bred to produce 7/8 Gelbvieh progeny was purchased to augment the Gelbvieh population in 1977 that were graded from a female population of Charolais × Angus with the same sample of Gelbvieh sires used in the Gelbvieh grade-up program at the Research Center. The Charolais population was established primarily with the purchase of registered purebred Charolais females in 1977 and was augmented by Charolais graded-up from an Angus × Hereford base at the Research Center started in 1967. Charolais sires were sampled from a broad genetic base. The Red Poll population was established from registered females purchased from several sources in 1966, 1967, and 1968 with sires sampled from a broad genetic base. The Hereford and Angus breeds were maintained as closed populations, except as noted, since approximately 1960. A sample of Hereford males and females was added in 1966, but this sample did not produce any male progeny that were used to maintain the population. A sample of Angus sires was introduced in 1967 and 1968 but no male progeny were produced from these matings that were used to maintain the population. Sires used to maintain the purebred populations were descended from males and females used in the foundation of the composite population to which a pure breed contributed. The purebreds have been maintained as registered populations recorded in the appropriate Herd Book of a breed record society.

Mating Procedure. All yearling females were exposed by natural service to yearling males for a mating season of 42 d. Since 1987 in Limousin and 1988 in Herefords, males 2 yr old or older were used on yearling females because of late puberty in both sexes of these breeds. Females 2 yr old and older were mated by artificial insemination for 28 d followed by natural service exposure to some of the same sires used in artificial insemination for 28 d for a mating season of 56 d. Most sires were used in two or more years, including their use in natural service on yearling heifers. From 1978 until 1984, the mating season for yearling heifers was from mid-May until late June and for females 2 yr old and older was from the first of June until late July. Since 1985, the mating season for yearling females was from late May until near mid-July and for females 2 yr old and older was from mid-June until near mid-August. This adjustment of approximately 2 wk in mating and calving season was made to allow greater synchrony of breeding and calving with nutritive and climatic environment. Mating season for yearling females ended immediately before the start of the natural service part of the mating season for females 2 yr old and older in order to use the same single sire mating pastures for both age groups. Open females were retained in all breed groups, unless they were open in two successive years, until 1985. Since 1985, all open females were removed each year from all breed groups. Nonperformance criteria, such as age, color, and extremes in skeletal size, have been used to remove excess females to maintain population size for each breed group. Where possible, an attempt was made to maintain a similar age distribution of females in each breed group. Males and females from the F_4 generation of each composite population were removed from the project at an age of 1 yr.

Females in all breed groups were assigned to sires on a stratified random basis within ages in all populations. Half-sib or closer matings were avoided.

The same basic criteria have been used to identify males for use in all populations. In all populations the intent has been to avoid extremes in regard to weight and condition and muscular and skeletal anatomy. Dystocia has been given consideration in identifying males for use in all breed groups. Larger scrotal circumference has been favored, particularly in breeds that are late to reach puberty (i.e., Hereford and Limousin) (Gregory et al., 1991d). Polledness and color patterns of red or red with white markings have been preferred for males used in all generations of each composite population. An effort was made to maintain a broad pedigree base in all breed groups. The occurrence of genetic defects in some breed groups (i.e., "double muscling" in Gelbvieh, MARC I and MARC II; "parrot mouth" in Gelbvieh and Braunvieh; malocclusion in Hereford, Angus, and Simmental; hydrocephalus in Red Poll and MARC III; and ataxia in Simmental) resulted in some compromise of pedigree breadth.

Management of Females. Generally, female populations were fed and managed consistent with their requirements. The general plan was to group females in three management units under the day-to-day supervision of an operations coordinator who had operational responsibility for this project. To the extent that a composite population and their contributing parental breeds could be run together in harmony with their feed and management requirements, this was done (i.e., all generations of composite MARC I and Braunvieh, Charolais and Limousin were managed together [Management Group 1], all generations of composite MARC II and Simmental, Gelbvieh, and Pinzgauer were managed together [Management Group 2], and all generations of composite MARC III and Hereford, Angus, and Red Poll were managed together [Management Group 3]). The only deviation from this practice was during the 28-d natural service breeding season when all females were in single sire mating pastures. The Pinzgauer females were managed with composite MARC II for two reasons: to balance numbers in the three management units and because the feed and management requirements of Pinzgauer females are similar to those for Simmental and Gelbvieh. Even though the populations were grouped in the three management units, every effort was made to apply uniform management protocols among the three units. Types of improved pastures (cool- and warm-season grasses), winter feeding programs, and all basic management practices were the same and were provided consistent with requirements. Pastures were contiguous and overlapped. All groups received the same feed but the amounts were varied consistent with requirements.

Two-year-old females were fed a mixture of corn silage and alfalfa haylage along with alfalfa and grass hay, starting from 2 to 3 mo before calving and continuing until pastures were adequate to meet their requirements, which was usually in mid to late April. All older females were fed mixtures of alfalfa and grass hay to meet nutritive requirements, usually from November until mid to late April. After 1986, economic considerations favored feeding these females limited quantities of corn silage and alfalfa haylage during the period of winter feeding.

Feeding Young Males. Calves were weaned at an average age of approximately 180 d. Mean birth date was April 7 and calves were weaned the 1st wk of October in most years. Following an adjustment period after weaning (28 d), males (intact) were fed a diet composed of corn silage, rolled corn, and protein-mineral-vitamin supplement (2.69 Mcal of ME/kg of DM, 12.88% CP) for 140 d.

Data Collection. Calves were weighed at birth, mid-breeding season (end of AI breeding period), at weaning, and 28, 84, 140, and 168 d after weaning. Height at hip was taken 168 d after weaning. Scrotal circumference was measured 168 d after weaning. Animals were scored for muscling, condition, and trimness at 168 d after weaning. The scale for muscling, condition, and trimness was the same across all breed groups. The score for muscling reflected differences in weight per unit of long bone length on a fat-constant basis; condition score reflected differences in subcutaneous fat; and trimness score primarily reflected differences in dewlap and sheath.

Calving difficulty was subjectively evaluated using descriptive scores (i.e., 1 = no difficulty, 2 = little difficulty by hand, 3 = little difficulty with calf jack, 4 = slight difficulty with a calf jack, 5 = moderate difficulty with calf jack, 6 = major difficulty with calf jack, 7 = Caesarean birth and, 8 = abnormal presentation). Percentage of calving difficulty was analyzed (scores 1 and 2 = 0; scores 3, 4, 5, 6, and 7 = 1. Calves with abnormal presentation were excluded from the analyses of calving difficulty. Twin calves and calves raised by foster dams were excluded from all analyses. Weights at 200 and 368 d were estimated using birth weight and preweaning and postweaning average daily gain, respectively.

Analysis of Data. Data were analyzed by least squares mixed model procedures (Harvey, 1985). Three primary analyses were conducted. The fixed effects included in the model were breed group (nine parental breeds in the model for purebreds, three composite populations in the model for composites, and nine parental breeds plus three composites in the model for combined analyses), year of birth, age of dam (2, 3, 4, and $\geq$ 5) of individual, and the regressions of each trait on date of birth and on date of birth within breed group. The regressions on date of birth and on date of birth within breed group were both significant for most of the traits included in the analyses. Interactions among main effects were not important ($P > .05$). Sire of individuals within breed group was included in the model as a random effect for each analysis. Separate analyses were run on calves with 1) dams of all ages, 2) calves with 2-yr-old dams, and 3) on calves with dams ≥ 3 yr old. The objective of the separate analyses for calves with 2-yr-old dams was to obtain estimates of h^2 and r_g involving calves with dams of this age. The separate analyses for calves with dams ≥ 3 yr was because data on gestation length were not available on calves with 2-yr-old dams because there was no AI in yearling heifers. Pooled estimates of variance components among sires (σ_s^2) and residual (σ_e^2) were used to estimate genetic (σ_g) and phenotypic (σ_p) standard deviations. Genetic standard deviations were estimated by $\sqrt{4 \times \sigma_s^2}$. Phenotypic standard deviations were estimated by $\sqrt{\sigma_s^2 + \sigma_e^2}$. Heritability ($h^2$) was estimated by $4\sigma_s^2/(\sigma_s^2 + \sigma_e^2)$. Coefficients of variation (CV) were computed $CV = \sigma p/\bar{x}$. Genetic and phenotypic correlations were calculated by $COV_{si\ sj}/(\sigma_{si} \times \sigma_{sj})$ and $COV\ P_i\ P_j/(\sigma P_i \times \sigma P_j)$, respectively, where s_i and s_j refer to genetic value of traits i and j and where P_i and P_j refer to phenotypic value of traits i and j.

In each analysis the component breed groups are assumed to have a common variance. The estimates of genetic (co)variances reflect average values for breed groups included in each of the three primary analyses.

The sire model provided by the LSMLMW program (Harvey, 1985) was chosen over alternative models and programs (e.g., DFREML, Boldman et al., 1993) because it was important to estimate covariances among a large number of traits in the analyses. Computing efficiency greatly favored the use of the sire model over alternative models. Also, the advantages of using MTDFREML are believed to be relatively small because the parental purebred and composite populations were unselected and matings provided for a low rate of inbreeding.

Results and Discussion

Genetic and Phenotypic Standard Deviations and Phenotypic Coefficients of Variation. Estimates of genetic (σ_g) and phenotypic (σ_p) standard deviations and phenotypic CV are presented in Table 2 for 1) all breed groups combined, 2) purebreds combined, and 3) composites combined. Differences in σ_g and CV were generally small and not important between all breed groups combined, purebreds combined, and composites combined. There was not a tendency for higher σ_g and CV for composites than for contributing purebreds. For traits associated with size, σ_p tended to be larger for composites than for contributing purebreds because phenotypic variation tends to be proportional to the mean. The low CV for height is noted for all groupings of populations. This reflects small σ_p relative to the means. There was a high degree of similarity for traits with a normal distribution (e.g., size) in CV in all groupings of populations. Because of the arbitrary nature of the scale for scores, CV are not presented for traits for which differences were evaluated by subjective score.

Heritabilities. Estimates of heritability (h^2) are presented in Table 3 for 1) all breed groups combined, 2) purebreds combined, and 3) composites combined. Generally, there was close agreement in h^2 among the three groupings. There was not a tendency for higher h^2 in composites than in contributing purebreds. Because of similarity of estimates among the three groupings and the smaller standard errors as a result of greater numbers, only estimates of h^2 for all breed groups combined are discussed. For all breed groups combined, traits associated with size (e.g., weight and height) were of intermediate heritability (e.g., .35 to .48). Heritability of scrotal circumference was of a magnitude similar to size traits (.43). Subjective scores for condition, muscling, and trimness were of similar magnitude and were at the lower end of the range of h^2 for size-related traits (e.g., .30 to .35). The h^2 for both expressions of calving difficulty (i.e., calving difficulty score and percentage requiring assistance) were of sufficient magnitude (.27 and .31, respectively) to suggest response to selection, among calves with 2-yr-old dams. The h^2 of calving difficulty (i.e., either calving difficulty score or percentage calving difficulty) was greater in calves with 2-yr-old dams than in calves with dams ≥ 3 yr. This is expected because of the higher frequency of calving difficulty in 2-yr-old dams (Gregory et al., 1991c). Estimates of h^2 tend to be higher than literature reports for 200-d weight but lower than literature reports for 368-d weight (Koch et al., 1982; Mohiuddin, 1993; Koots et al., 1994a). The h^2 of gestation length in females ≥ 3 yr was among the highest of traits analyzed (.46).

Koots et al. (1994a) provided analyses and summary of published estimates of heritability for beef production traits. For calving ease, expressed as percentage unassisted (direct), they reported weighted mean h^2 estimates of .13 for cows and .10 for heifers. Our h^2 estimates are higher for calving difficulty score of .27 for heifers, .13 for cows, and .26 for females of all ages as a trait of the calf. Our h^2 estimates of .43 for age-adjusted scrotal circumference is in close agreement with the weighted mean estimate of .48 reported by Koots et al. (1994a). As traits of the individual, Koots et al. (1994a) reported weighted mean h^2 for growth traits as follows: birth weight .31, preweaning gain .29, weaning weight .24, postweaning gain .31, yearling weight .33, and yearling height .61. Our h^2 estimates for growth traits tend to be higher, except for 368-d weight, which is similar (.35), and for 368-d height, which is lower (.48).

Genetic Correlations. Genetic correlations among size traits, calving difficulty score and percentage, and gestation length are presented in Table 4 for all breed groups combined. Genetic correlations among size

Table 2. Least squares means, genetic and phenotypic standard deviations, and phenotypic coefficient of variation for all breed groups, purebreds, and composites – intact males

	All breed groups				Purebreds				Composites			
Trait	σ_g	σ_p	$\bar{x}$	CV	σ_g	σ_p	$\bar{x}$	CV	σ_g	σ_p	$\bar{x}$	CV
Birth wt, kg	3.3	5.0	42.6	.12	3.5	4.7	42.6	.11	3.2	5.3	43.3	.12
Preweaning ADG, kg	.064	.104	.952	.11	.048	.099	.959	.10	.059	.105	.987	.11
200-d wt, kg	13.1	22.0	233	.09	11.0	21.0	234	.09	11.8	22.5	241	.09
Postweaning ADG, kg	.090	.138	1.235	.11	.089	.134	1.241	.11	.086	.141	1.261	.11
368-d wt, kg	21.1	35.8	440	.08	21.4	34.1	443	.08	20.0	37.4	453	.08
368-d ht, cm	2.38	3.42	124	.03	2.06	3.23	125	.03	2.45	3.55	124	.03
368-d cond. score[a]	.473	.810	4.8	—	.472	.785	4.6	—	.456	.858	5.2	—
368-d muscle score[b]	.376	.639	5.3	—	.396	.660	5.3	—	.332	.607	5.2	—
368-d trim. score[c]	.475	.817	3.8	—	.497	.814	3.9	—	.420	.812	3.9	—
368-d scrotal cir., cm	1.602	2.444	32.5	.08	1.528	2.410	32.4	.07	1.613	2.467	33.2	.07
C.D. score, all ages[d]	.434	.844	1.5	—	.453	.857	1.5	—	.407	.827	1.5	—
C.D., %, all ages[e]	15.4	33.6	23.8	—	14.8	34.0	23.8	—	16.1	33.1	22.8	—
C.D. score, 2 yr[d]	.70	1.30	2.4	—	.78	1.28	2.4	—	.59	1.33	2.4	—
C.D. %, 2 yr[e]	26.70	45.82	62.4	—	25.84	45.43	62.2	—	27.89	46.31	62.9	—
C.D. score, ≥ 3 yr[d]	.22	.59	1.2	—	.29	.62	1.2	—	.06	.55	1.1	—
C.D. %, ≥ 3 yr[e]	7.34	27.34	11.2	—	9.75	28.21	11.5	—	.00	26.23	8.6	—
Gestation length, ≥ 3 yr	2.71	3.75	288	.01	2.66	3.78	288	.01	261	3.72	288	.01

[a]1 to 9; 9 = very fat, 1 = emaciated.
[b]1 to 9; 9 = very thick muscled, 1 = very thin muscled.
[c]1 to 9; 9 = very lacking in trimness, 1 = very trim.
[d]1 = no difficulty, 2 = little difficulty by hand, 3 = little difficulty with calf jack, 4 = slight difficulty with calf jack, 5 = moderate difficulty with calf jack, 6 = major difficulty with calf jack, 7 = Caesarean birth.
[e]Scores 1 and 2 = 0; scores 3, 4, 5, 6, and 7 = 1.

Table 3. Heritabilities (h^2) and standard errors (SE) for all breed groups, purebreds, and composites - intact males

Trait	All breed groups (n = 7,536)		Purebreds (n = 4,115)		Composites (n = 3,421)	
	h^2	SE	h^2	SE	h^2	SE
Birth wt, kg	.44	.04	.54	.06	.37	.05
Preweaning ADG, kg	.38	.04	.24	.04	.32	.05
200-d wt, kg	.35	.04	.27	.04	.27	.05
Postweaning ADG, kg	.43	.04	.44	.05	.37	.05
368-d wt, kg	.35	.04	.40	.05	.28	.05
368-d ht, kg	.48	.04	.41	.05	.48	.06
368-d cond. score[a]	.34	.04	.36	.05	.30	.05
368-d muscl. score[b]	.35	.04	.36	.05	.30	.05
368-d trim. score[c]	.34	.04	.37	.05	.27	.05
368-d scrotal circum., cm	.43	.04	.40	.05	.43	.06
C.D. score, all ages[d]	.26	.03	.28	.04	.24	.05
C.D. %, all ages[e]	.21	.03	.19	.04	.24	.05
C.D. score, 2 yr[d]	.27	.08	.34	.12	.19	.12
C.D. %, 2 yr[e]	.31	.09	.30	.12	.33	.13
C.D. score, ≥ 3 yr[df]	.13	.05	.21	.07	.01	.07
C.D. %, ≥ 3 yr[ef]	.07	.05	.12	.07	.00	.00
Gestation length, ≥ 3 yr[f]	.46	.06	.44	.09	.44	.10

[a]1 to 9; 9 = very fat, 1 = emaciated.
[b]1 to 9; 9 = very thick muscled, 1 = very thin muscled.
[c]1 to 9; 9 = very lacking in trimness, 1 = very trim.
[d]1 = no difficulty, 2 = little difficulty by hand, 3 = little difficulty with calf jack, 4 = slight difficulty with calf jack, 5 = moderate difficulty with calf jack, 6 = major difficulty with calf jack, 7 = Caesarean birth.
[e]Scores 1 and 2 = 0; scores 3, 4, 5, 6, and 7 = 1.
[f]Calves conceived by artificial insemination.

traits were highly variable, ranging from −.02 ± .07 between birth weight and preweaning ADG and .97 ± .01 between preweaning ADG and 200-d weight. The low r_g between preweaning and postweaning ADG (.04 ± .07) is much lower than other reports (Koch et al., 1982; Koots et at., 1994b). The r_g of birth weight with calving difficulty score and calving difficulty percentage were similar in calves from dams of all ages, 2-yr-old dams and dams ≥ 3 yr, ranging from .55 ± .13 to .82 ± .29.

The r_g of .62 ± .04 between 368-d weight and 368-d height suggests that selection for either would be expected to result in changes in the other. The r_g between muscling score and height was low (−.10 ± .07). The r_g between 368-d weight and 368-d condition score was relatively low (e.g., .24 ± .07). The higher r_g of birth weight with calving difficulty score and percentage calving difficulty (i.e., from .55 ± .13 to .82 ± .29) than of birth weight with 368-d weight (i.e., .36 ± .06) suggests an opportunity to reduce calving difficulty by reducing birth weight while maintaining 368-d weight. A similar conclusion was drawn by Dickerson et al. (1974) in which a selection index of I = [(368-d weight) − (3.2 × birth weight)] was suggested. Mendoza and Slanger (1985) reported results suggesting opportunity to reduce birth weight while maintaining yearling weight. The relatively high r_g of gestation length with calving difficulty score and with percentage calving difficulty (i.e., .57 ± .18, .54 ± .26) suggests that some reduction in gestation length should favor reduced calving difficulty. The relatively low r_g between gestation length and birth weight (.21 ± .11) is noted. The r_g of scrotal circumference with other traits evaluated was generally low.

Koots et al. (1994b) provided analyses and summary of published estimates of genetic (r_g) and phenotypic (r_p) correlations among beef production traits. Our estimates of r_g of the two expressions of calving difficulty with birth weight, weaning weight, and yearling weight for calves with dams of different ages are in general agreement with Koots et al. (1994b) report of calving ease (direct) of −.74 with birth weight (direct), −.21 with weaning weight (direct), and −.29 with yearling weight (direct). Our estimates of r_g among growth traits generally are lower than their weighted mean values for r_g among growth traits. The unrealistically low r_g between preweaning and postweaning average daily gain (.04 ± .07) in our study is considerably lower than the weighted mean genetic value reported by Koots et al. (1994b) of .47. We do not have an explanation for the low estimate obtained in our study. The r_p was .20 and environmental correlation was .31 between preweaning and postweaning average daily gain in our study. The r_g of scrotal circumference with 368-d weight was .18 ± .07 in our study compared with a weighted mean value of .39 from the published estimates reported by Koots et al. (1994b).

Phenotypic Correlations. Phenotypic correlations among size traits were intermediate to high. The r_p among different anatomical scores generally were low.

Table 4. Genetic[a] and phenotypic[b] correlations among production traits of intact males

Trait	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.
1. Birth wt		.15	.37	.30	.42	.44	.01	.07	.00	.11	.32	.26	.53	.42	.26	.24	.27
2. Preweaning ADG	−.02 ± .07		.97	.20	.73	.46	.17	.11	.08	.31	−.03	−.02	−.02	.02	−.06	−.04	.01
3. 200-d wt	.24 ± .07	.97 ± .01		.25	.78	.54	.16	.12	.08	.32	.04	.04	.09	.10	.00	.02	.07
4. Postweaning ADG	.30 ± .06	.04 ± .07	.11 ± .07		.80	.48	.30	.16	.08	.23	.09	.07	.13	.12	.06	.05	.04
5. 368-d wt	.36 ± .06	.63 ± .04	.70 ± .04	.79 ± .03		.64	.30	.18	.10	.34	.08	.07	.14	.14	.04	.04	.07
6. 368-d ht	.40 ± .06	.46 ± .06	.55 ± .05	.39 ± .06	.62 ± .04		−.07	−.09	.00	.25	.11	.10	.17	.16	.06	.06	.11
7. 368-d cond. score	−.07 ± .07	.01 ± .08	−.01 ± .08	.34 ± .07	.24 ± .07	−.23 ± .07		.10	.26	.10	.00	−.02	.01	.00	.00	−.03	.00
8. 368-d musc. score	.31 ± .07	.05 ± .08	.13 ± .08	.24 ± .07	−.26 ± .07	−.10 ± .07	.12 ± .08		−.08	.00	.04	.05	.06	.06	.05	.04	−.02
9. 368-d trim score	−.16 ± .07	.15 ± .08	.10 ± .08	−.08 ± .07	.01 ± .08	−.10 ± .07	.25 ± .07	−.20 ± .08		.06	−.02	−.04	−.03	−.04	−.01	−.02	.01
10. Scrotal circum.	.01 ± .07	.26 ± .07	.26 ± .06	.02 ± .07	.18 ± .07	.30 ± .06	.08 ± .07	−.17 ± .07	.13 ± .07		−.20	−.20	.01	.02	−.05	−.04	−.02
11. CD score (all ages)[c]	.60 ± .06	−.09 ± .08	.06 ± .08	.21 ± .08	.19 ± .08	.24 ± .07	.04 ± .08	.12 ± .08	−.11 ± .08	−.06 ± .08		.77					
12. CD, % (all ages)[c]	.59 ± .06	.05 ± .09	.20 ± .09	.27 ± .08	.32 ± .09	.31 ± .08	−.04 ± .09	.19 ± .09	−.09 ± .09	−.06 ± .09	.93 ± .02						
13. CD score, 2-yr-olds[c]	.62 ± .12	−.08 ± .13	.00 ± .14	.11 ± .14	.07 ± .15	.14 ± .13	−.20 ± .15	.33 ± .16	−.29 ± .14	−.17 ± .18				.80			
14. CD%, 2-yr-olds[c]	.55 ± .13	.09 ± .12	.16 ± .13	.22 ± .13	.27 ± .13	.23 ± .12	−.08 ± .14	.44 ± .15	−.23 ± .13	−.10 ± .17			1.00 ± .05				
15. CD score, ≥ 3 yr[c]	.62 ± .17	−.06 ± .22	.12 ± .21	.11 ± .19	.14 ± .19	.38 ± .17	−.29 ± .21	−.21 ± .20	−.31 ± .20	−.25 ± .19						.79	.11
16. CD%, ≥ 3 yr[c]	.82 ± .29	.15 ± .30	.36 ± .30	.17 ± .25	.30 ± .26	.54 ± .26	−.28 ± .30	−.12 ± .27	−.23 ± .27	−.14 ± .25					1.00 ± .22		.11
17. Gestation length, ≥ 3 yr	.21 ± .11	−.15 ± .14	−.08 ± .13	.16 ± .12	.07 ± .12	.13 ± .10	−.08 ± .13	.19 ± .12	−.11 ± .12	−.34 ± .11					.57 ± .18	.54 ± .26	

[a]Genetic correlations and their standard errors are below diagonal.
[b]Phenotypic correlations are above diagonal.
[c]CD = calving difficulty.

As expected, a high r_p (.77, .80, and .79) between calving difficulty score and percentage calving difficulty was observed in females in different age classes. The r_p of calving difficulty score and percentage calving difficulty with gestation length were low (.11) in females ≥ 3-yr-old.

Implications

Composite breeds of cattle are similar to their contributing purebreds in phenotypic and genetic variation for growth and size traits. Thus, response to selection should be similar. Selection for reduced calving difficulty score should be moderately effective based on a heritability of .27 for calves with 2-yr-old dams. Further, because of the higher genetic correlation between birth weight and calving difficulty score (.62) in calves with 2-yr-old dams than between birth weight and 368-d weight (.36) there is opportunity to reduce calving difficulty by reducing birth weight while maintaining 368-d weight. Even though there is an optimum gestation length, the relatively high genetic correlation between gestation length and calving difficulty score (.59) suggests opportunity to reduce calving difficulty score by some reduction in gestation length.

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